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Investigation and Performance analysis of evacuated tubes coupled double basin solar still with fins

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Abstract- *In present research paper, work has conducted on evacuated tubes coupled double basin solar still with and without the use of pin fin. 3 cm depth of water has taken for the consideration for the high research work. From the one-year research work, it has found 34.3% increment with the use of pin fin compared with alone. At last, the comparison has been made with other researchers work, and it has been found 300% enhancement in distillate output compared with conventional solar still by considering 3 kg average distillate production from conventional solar still.*

Keywords—*Evacuated tubes,distillate output,double basinSolar still, fin*

I. INTRODUCTION

A simple way of distilling water is by evaporation and condensation method. In solar still, the water is evaporated using solar energy. In solar still, impure water is taken in a well-insulated air tight basin covered with transparent plastic/glass cover. Practically, solar still is termed as passive solar still. When the cover is exposed to sun, radiation energy is transmitted through transparent cover, falls in the basin, absorbed by the basin absorber plate, converted into heat and transferred to water. The water gets heated up, transfer heat to air inside the still and the air become unsaturated. The water evaporates and makes the air inside still saturated. This air is subjected circulatory motion due to the temperature difference between water surface and cover lower surface. When high temperature air touches the cover, becomes cool and the water present in the air condenses at the lower surface of the cover. This condensed water slides down and is collected using a drain.

The transparent cover receives and transmits radiation into the still. Likewise, the condensation takes place along its lower surface. Also, it should suppress thermal radiation in the atmosphere. Glass is the best material to cover (**Duffie et al. [1]** since it has higher transmittance and less reflectivity. Also glass is opaque to thermal radiation. For higher latitude places, single slope still is preferable, and for northern Chemosphere the still faces south (**Fath et al. [2]**. The inclination of the cover is optimized to collect the accumulated condensate through drain before it drops down to the basin. The condensate mass accumulation depends on solar intensity and condensation rate. They also conducted indoor simulation experiments and found that the production rate is higher for 30° cover inclination. Glass temperature affects the condensation rate at its lower surface. Lower glass surface temperature increases the circulation of air inside the still which enhances convective and evaporative heat transfer between basin water and glass. Also, cooler glass lower surface increases condensation. The glass cover temperature is reduced by continuous flow (**Abu-Hijleh [3]** or intermittent flow (Tiwari and Madhuri, 1985) of raw cooling water on the cover. The cooling water gains latent heat from condensing water and regenerates it in the basin. The second effect of evaporation and condensation takes place between the covers as shown in. **Bassam A/K Abu-Hijleh et al. [4]** result shows increase in production by 20%. Yousef and **Mousa Abu-Arabi [5]** results also show that, the use of the film-cooling increases the still efficiency up to 20%. Lawrence et al. (1989) had carried out research work on varying mass flow rate of water of upper side of glass cover to see its effect on distillate output and efficiency of solar still. They found that, enhancement of distillate output and efficiency was 9% and 5%, respectively, when the mass flow rate was 1.5 m/s. Wind velocity is also having its effect on the temperature of the glass. At higher wind velocity, due to higher convection heat transfer from the glass to atmosphere the productivity of the still is increasing (**Yousef et al., 2004 and El-Sebaii [6] Tiwari and Rao** [7] theoretically analyzed the effect of water flowing over the glass cover in a single basin still. The result shows the productivity is increased with flowing water over the glass cover. Also, the yield decrease when the water flow rate increases. **Pr. K. Abdenacer and S. Nafila [8]** had conducted lots of experiments on passive and active solar still based on water temperature and efficiency and found that, the active solar still always increased distillate output compared with passive solar still. **Sebaii et al., [9]** had fabricated passive solar still to find the optimum glass cover inclination. They performed studies to see best glass cover inclination during winter and summer. It was found that the optimum glass cover inclination was 33.3° N (Latitude of the place) for both summer and winter. **M.K. Phadatare, S.K. Verma, [10]** had evaluated the performance of a solar still with 4 mm plexiglass as a cover material to see the effect on the internal heat transfer coefficient and distillate output by varying the depth of brine. They found that, plexiglass of 4 mm thickness found an enhancement of distillate output by 2 cm brine thickness.
Karuppusamy [11] had conducted several experiments on single basin solar still coupled with evacuated tubes in climate conditions of Chennai to see effect of increase in water temperature on distillate output of solar still. He took 0.03 m depth of water inside solar still and tested for one year and found that, the distillate output increased by more than 100%

compared with conventional solar still.**Shobha et al.[12]**had conducted simple experiment on single basin solar still coupled with evacuated tubes with help of pipes. They conducted solar still with evacuated tubes to see effect on distillate output. They found 110% increment in distillate output.**Rahuldev and G N Tiwari [13]**had carried out several experiments on single basin solar still coupled with evacuated tubes in climate conditions of New Delhi,India. They also conducted theoretical analysis to see the difference between experimental and theoretical analysis and found good agreement in terms of coefficient of correlation. **J. Xiong et al. [14]**fabricated and tested innovative design of single basin solar still coupled with evacuated tubes. They used stacked tray in the solar still in such a way that the latent heat of condensation can be utilized properly and found increment in distillate output. **Deniz [15]** had conducted research work on single basin solar still with various energy absorbing materials and tested in climate conditions of Oman. He also carried out theoretical analysis and compared with experimental results and found good agreement between them.

Literature review exhibited that the solar still is a very important device to convert available brackish water into drinkable water by use of solar energy. Many of the researchers have worked on it for increment in distillate output. For increment in distillate output, evacuated tubes are generally used. But the main problem of loss of latent heat of condensation remains unsolved in solar still when it coupled with evacuated tubes. Hence, in this present research paper, work has done on evacuated tubes coupled double basin solar still for usage of loss of latent heat of condensation. Also, fins have not used by the researchers for increment in surface area. Hence, main aim of this present work is to fabricate evacuated tubes coupled double basin solar still with pin fin for increment in distillate output.

II. EXPERIMENTAL SET UP

Fig.1 shows the experimental testing set up made by locally available materials in market of Patan, Gujarat. Fig.2 shows the pin fin used in present experiment. Present experimental set up consists of 1 meter square cross sectional area. It used two glass cover for top and bottom basin. Bottom basin contains attachment of evacuated tubes with help of holes. The main use of direct attachment of evacuated tubes that, the heat loss from the evacuated tubes to pipe is reduced. Upper basin attached with lower basin with help of glass cover. Dimensions of lower and upper basin are 1006 mm *1000 mm *500 mm. The fin size of 3 cm used in present experiment. All the experiments have conducted at clear sky conditions with constant water depth of 0.03 cm during January 2016 to December 2016.

Fig.1. Experimental set up of double basin solar still with evacuated tubes

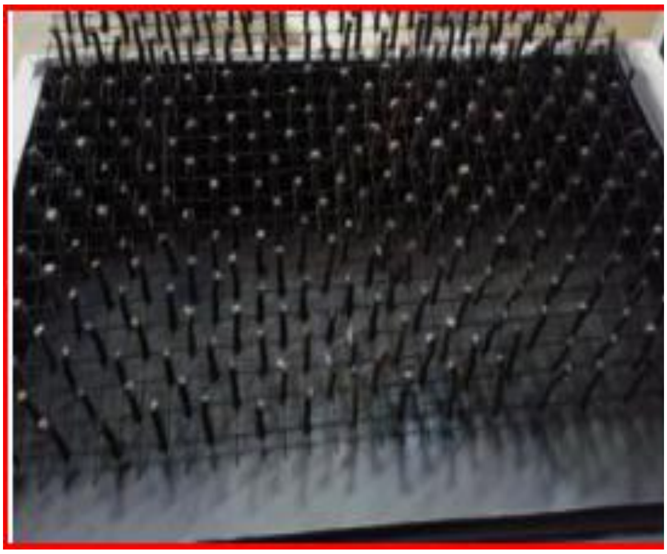

Fig.2 pin fin arrangement provided in solar still

III. RESULT AND DISCUSSION:

Generally in all solar energy research work the output depends on amount of solar energy incident on it. Also, the solar radiations increased from morning to noon and then start reducing due to movement of sun towards the south. Fig. 3 shows comparison between the water circulation inside solar still from evacuated tubes. It has found that, the increment in solar intensity increased the radiation incident on evacuated tubes for increment in natural circulation towards the solar still.

Fig. 4 shows that the hourly variations of solar intensity and ambient temperature on 10th May and 10th January. 2015. It exhibits that, solar radiation upsurgestill it influences its supreme value at mid-day, then it fall again. This curve is detected in both summer and winter investigational days. The highest recorded value of solar intensities was 980 and 960 W/m2 and 600 and 620 W/m2 for vacuum tubes and solar still during 10th May and 10th January 2015. The maximum ambient temperature is originateapproximately 36 °C and 24 °C during 10th May and 10th January, 2015

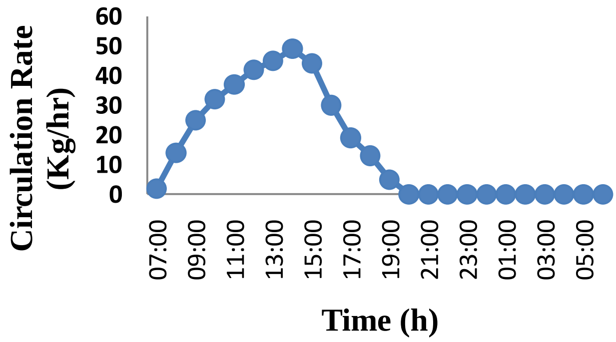

Fig.3 Hourly circulation of water inside the vacuum tubes

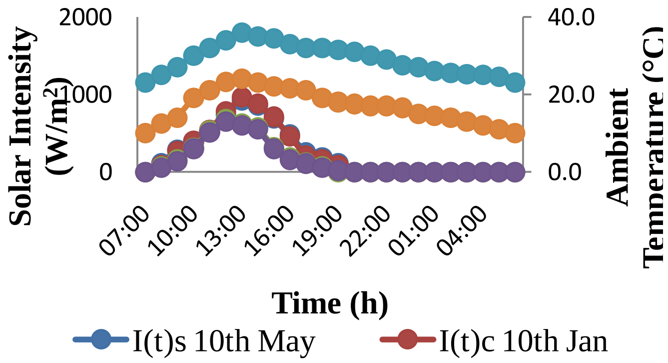

Fig. 4 Hourly variation of solar intensity and ambient temperature for DBSWVT during summer experimental days

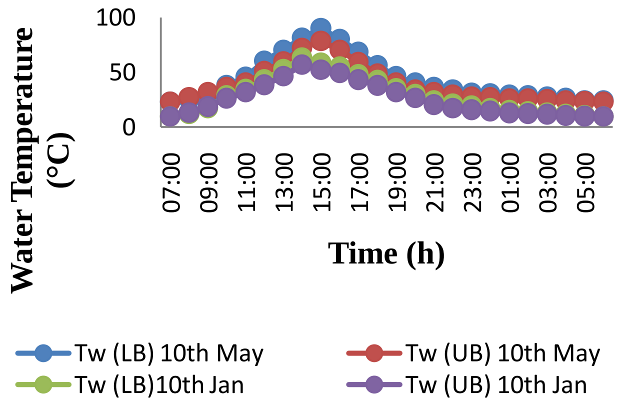

Fig. 5 Temperature of water in upper and lower basin without use of fins.

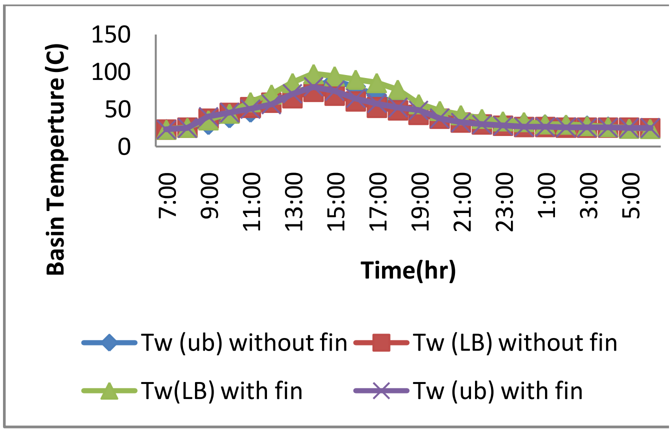

Fig. 6 Temperature of water in double basin evacuated tubes coupled solar still with and without fins

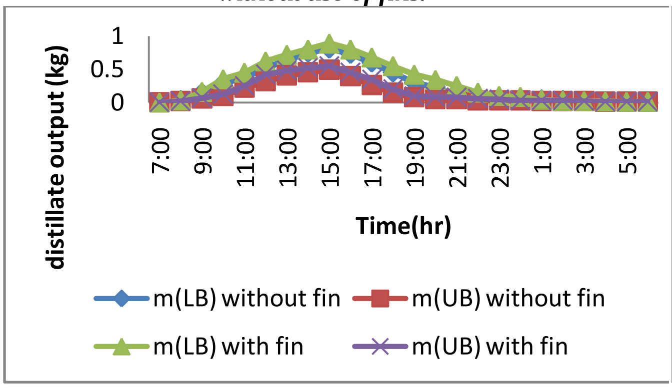

Fig. 7 Distillate output received from evacuated tubes coupled solar still with and without use of fins

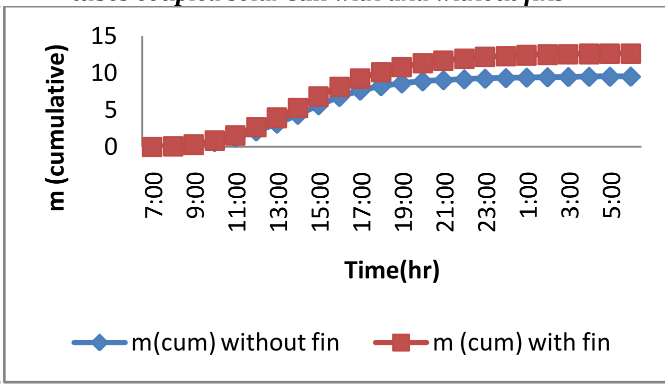

Fig. 8 cumulative output received from evacuated tubes coupled solar still with and without use of fins

Fig. 5demonstratesthe difference of water temperatures of lower and upper basin during summer and winter experimental days of 10th May and 10th January, 2015. It is shown that, the maximum temperature of the water inside the upper and lower basin remains higher during the experimental summer day compared with winter experimental day due to higher solar radiation and ambient temperature of the location. It is also shown that water temperature increased during the day until it reaches its maximum value at 15:00 pm and then reduced slowly during summer experimental day and winter experimental day found maximum value at 14:00 pm and then reduced drastically compared with summer experimental day. The reason is the volumetric heat capacity of water inside lower and upper basin is responsible for the gradual and drastic reduction in water temperature. Water temperature reaches its maximum value was 90.2 °C and 78.4 °C during summer experimental day and 63.2°C and 56.7°C. Climate condition always affects the temperature gained by passive solar still during summer and winter experimental day, hence summer and winter experimental day, maximum temperature achieved at 15:00 pm and 14:00 pm. It is also observed that the lower basin water temperature remains high throughout the day during summer and winter experimental day, due to augmentation of vacuum tubes. During experimental winter day, the temperature is found more than 60 °C during 14:00 pm. Water temperature of passive solar remains lower during winter, but here lower basin removes excess heat to the upper basin. Hence water temperature remains higher during peak hours. It is the principal advantage found in this arrangement.

Fin attachment at lower and upper basin found more productive as shown in Fig. 6. Fin has characteristic of having increment in heat transfer due to the enhancement of area. Also, they are porous, hence, it does not only increment the water temperature during daytime but also during the off-sunshine hours. Fig. 6, it is clearly shown that the temperature of water reaches to 97 degree Celsius and it remains about 90 during two continuous hours.

Fig. 7 signifies the distillate output received by solar still with and without attachment of fins. It is found that the fins enlarged the superficial area of water; hence due to the raise in water temperature, its distillate output was improved. Extreme distillate output received was up to 0.90 kg during 3 pm. Fins have shown remarkable effect during off-sunshine hours as expected. Attachment of fins increased the distillate output not only for the lower basin but also from the upper basin. Fig. 8 shows cumulative distillate output gained by evacuated tubes coupled solar still with and without use of fins. It has found that, the solar still with fins gained 12.61 kg distillate output and without fins gained 9.5 kg. Hence, the increment of 32.75% distillate output compared with alone solar still. The reason behind increment in distillate output was due to the increment in surface area of water. Fig. 9 shows yearly comparative analysis of solar still with and without use of fins. It has found that, the average distillate output of solar still without use of fins found 9.12 kg and with fins 12.25 kg. Hence, average yearly increment in distillate output of 34.3% found in solar still with use of fins.

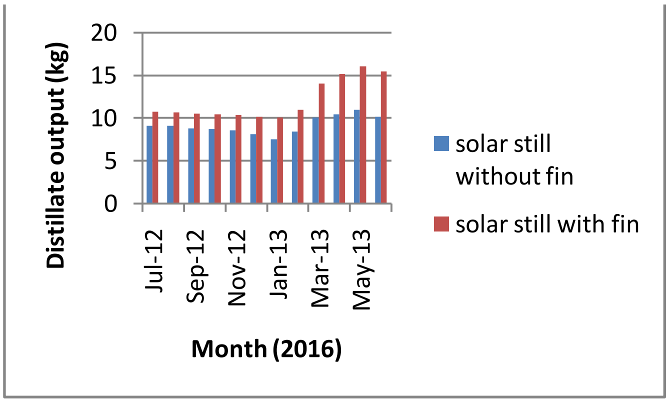

Fig. 9 comparison of solar still with and without use of fin

Table 1 shows the comparison of other researchers work with present research. It has found that, the present work found 300% increment in distillate output compared with conventional solar still.

Table 1: Comparison with other researchers work with present work

Sr. No.	Name of Researcher	Type of attachment with passive solar still	Increase in distillate output (%)
1	Dev and Tiwari, (2012)	Evacuated tube collector coupled with passive solar still	32%
2	SampathkumarKaruppusamy (2012)	Evacuated tube collector with granite gravel	59.78%
3	Xiong. et al. (2013)	Multi-effect passive solar still integrated with evacuated tubes and corrugated sheet	90%
4	Z. M. Omara et al. (2013)	Evacuated tubes with wick materials	108%
5	Present work	Double basin solar still with evacuated tubes and fins	300%

IV. CONCLUSION:

From the above research works following points were concluded:

- Evacuated tubes coupled double basin solar still was a better solar still for converting available brackish water into drinkable water by use of solar energy.
- Attachment of fins with coupled double basin solar still found above 30% increment in distillate output compared with without attachment of fin in same still.
- Annual distillate output of evacuated tubes coupled solar still with pin fin found 34.3% increment compared with without fin attachment.
- Evacuated tubes coupled double basin solar still with pin fin found 300% increment in distillate output compared with conventional solar still.

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